REMARKS

This amendment is submitted in reply to the Office Action mailed September 6, 2009 ("the Action"). Claims 1-67 are pending in the application. The claim numbering is based on the claim numbering submitted (corrected) with the Preliminary Amendment filed April 6, 2005. That Amendment noted that there was a numerical error in the original claim set (the number "34" was skipped).

I. The § 112 Rejections

Claims 3, 4 and 49-52 stand rejected for the use of acronyms. Applicant has canceled and/or defined the acronyms in the pending claims.

Claims 45-48 stand rejected for the "means for" language. The Examiner opines that it is unclear what structure is included in this recitation (but acknowledges para. 108 of the publication of the pending application). Nonetheless, the Examiner has examined the claims without invoking §112, paragraph 6.

First, Applicant respectfully notes that Claim 48 does not recite "means for" language and requests that this rejection be withdrawn with respect to at least this claim. However, Claims 44-47 recite "means for" language. The claim numbering is based on the Listing of Claims as submitted in the April 2005 Preliminary Amendment noted above.

Applicant respectfully directs the Examiner's attention to, *inter alia*, Figures 2-7B and pp. 10-22 of the specification as well as the Examples section, which describe and illustrate exemplary structures associated with the "means for" recitations. The application describes various earphones, headphones and ear-supported components that can transmit the FAF signal. Accordingly, Applicant respectfully requests that these rejections be withdrawn.

II. The §102(b) Rejection based on U.S. Patent No. 5,794,203 to Kehoe ("Kehoe")

The Action rejects Claims 1-3, 5, 12, 14, 16, 17, 45 and 46 under 35 USC §102(b) as being anticipated by Kehoe (citing to col. 4, lines 10-38).

The Action states that Kehoe teaches administering FAF to a subject having a non-

stuttering pathology while the subject is speaking or talking (citing to col. 4, lines 10-38). At this location, Kehoe describes a biofeedback system for speech disorders to promote fluency. More specifically, this text describes an electromyography (EMG) and frequency-altered feedback (FAF) circuit. The controller receives data from the EMG regarding muscle tension in the user's vocal folds, masseter and/or other speech-production muscles. The controller then controls the pitch of the FAF circuit in accordance with the user's muscle tension (col. 4, lines 16-24). When the user speaks fluently, with his speech production muscles relaxed, he hears his voice shifted lower in pitch. This downward shift is relaxing and pleasant, sort of like hearing James Earl Jones speak. (col. 4, lines 28-31).

Notably, Kehoe is directed to treating <u>stuttering</u> speech or fluency-related speech disorders. It is well known to use FAF for treating stuttering as noted in the background of the above-referenced pending patent application. *See also,* Kehoe, col. 2, lines 55-65 and col. 3, lines 1-5. That is, the use of FAF (frequency altered feedback) to treat stuttering is known. However, embodiments of the instant invention are directed to treating certain <u>non-stuttering and non-fluency</u> speech and/or language disorders using FAF. <u>Stuttering does not share the same underlying pathophysiology with other of the claimed conditions</u>.

The Abstract of Kehoe states that the biofeedback system detects disfluent speech and provides auditory feedback in accordance with the disfluency to enable immediate and carryover fluency. Kehoe states that it is a biofeedback system for treating "speech disorders". (col. 1, lines 6-8, line 20, col. 4, line 49, col. 5, lines 5-8).

Applicant notes that Kehoe does state that the proposed device can be used to develop fluency in daily conversations, when a speech-language pathologist cannot be present <u>to enable "persons of limited mental capacity (*e.g.*, Down's syndrome) to **develop fluency**</u>." (col. 5, lines 13-15)(emphasis added). Again, this text merely proposes to treat disfluency speech disorders.

Applicant has amended Claims 1, 44 and 46 to clarify that the administering step and/or device is for a subject or user having (a) a <u>non-stuttering non-fluency related language</u> pathology and/or (b) <u>a reading disability to improve reading comprehension</u>.

Further, in contrast to the statement regarding Claim 45 (46) at page 4 of the Action,

the device of Kehoe does not have the same functionality as it requires the use of an EMG with a circuit to output the FAF.

Applicant respectfully submits that Kehoe fails to teach or suggest the claimed subject matter and requests that this rejection be withdrawn.

III. The §102(b) Rejection based on U.S. Patent No. 6,644,973 to Oster ("Oster")

The Action also rejects Claims 1, 2, 5, 6, 44, 47, 48 and 59 as allegedly being anticipated by Oster. The Action alleges that Oster teaches the use of FAF to improve reading speed and comprehension.

Oster describes a "reading coach" with a band pass gain in the 750-4000 Hz range and a mirror. The system filters out low frequency sound while amplifying frequencies in the middle range. The frequencies toward the middle of the range receive the peak decibel enhancement (a peak decibel enhancement of 6 dB) while frequencies toward the high end are amplified to a lesser decibel enhancement (col. 3, lines 43-53). Oster states that the system provides immediate aural feedback in the speaker's own voice (not as normally heard conducted through and dampened by the jaw bone, but naturally in a brighter, higher tone)(col. 2, line 65 - col. 4, line 1). Oster filters low frequency sounds and amplifies the high and mid-range frequencies in the user's voice; it does not shift the frequency. Indeed, Oster states that the increased vocal output in the range 1000-4000 Hz more accurately reflects the tone of the voice as heard by others (col. 4, lines 60-61). The speakers voice is in no way or means shifted in the frequency/spectral domain.

In addition, if it is the Action's position that because the Oster system filters out the low frequency sounds and emphasizes the high and mid-range sounds, it generates a "frequency altered feedback", Applicant respectfully disagrees. As clearly understood by those of skill in the art, an FAF signal shifts the frequencies of a user's voice, *e.g.*, shifts the (digital) signal within a range of about +/- 2 octaves creating an "unnatural" voice feedback. *See also*, page 17 of the pending application. Oster proposes a system that encompasses high-pass filtering and band-passed enhancement (*i.e.*, gain) to provide a louder signal that is not shifted in the frequency/spectral domain.

In view of the foregoing, Applicant respectfully submits that the claims are not anticipated by Oster as Oster fails to teach the use of a FAF signal as claimed. Indeed, Applicant respectfully submits that Oster teaches away from the claimed subject matter as Oster merely provides a decibel enhancement to increase vocal output within the band pass of 1000-4000 Hz (col. 4, lines 60-61) to generate the sound of their own natural voice in a brighter, higher tone (col. 4, lines 1-3). *See also*, Kehoe, col. 2, lines 55-66 describing FAF and noting conventional examples of "alien", "robot" and low pitch sounds that can be generated using FAF (albeit to treat stuttering).

IV. The §103 Rejection based on Kehoe

In addition, the Action rejects Claims 5, 7-11, 13, 15 and 18-23 as being obvious over Kehoe and Claims 4, 24-26, 28-31, 33-43 and 46-67 as being obvious over Kehoe in light of SpeechEasy (a brochure dated March 2002). Claims 6, 27 and 32 are rejected as being obvious over Kehoe, SpeechEasy and Oster. Applicant respectfully disagrees.

Applicant agrees that portable devices that can generate FAF signals are known. However, the mere fact that FAF signals and portable devices have been used for treating stuttering does not render obvious the claimed feedback for treating other non-related conditions. Indeed, such a conclusion would imply that the different pathologies share the same underlying pathophysiology, which they do not.

Notably, with respect to Claims 5, 7-11, 13 and 15 and 26, 28, 30, 33, 34 and 36, the Action concedes that Kehoe fails to teach treating the claimed maladies, but alleges that it would have been obvious to use the method of Kehoe on patients having the claimed maladies "as an ordinary medical decision." (Action, pp. 5-6 and p. 7). Applicant strongly disagrees. Indeed, while FAF has been shown to increase reading comprehension in students with impaired reading ability, those same studies also indicated no improvement with subjects having "normal" reading ability. Thus, FAF is not a "magic potion". It is overstating the expectation of success for treating very different conditions with different causes and different communication skill issues associated with the different maladies. One of skill in

the art would not have been motivated to use FAF to treat the different conditions as an "ordinary medical decision."

The Action also states in several places that the method would be predictable and that treating a different patient with the known method "would have a high expectancy of success" because the patient would be treated by the method. The Action goes on to state that the claims do not require any actual degree of success in the actual treatment method, regarding the cure of the malady. (The last sentence appears to contradict the prior high expectancy of success statement). Again, Applicant strongly disagrees. There is no motivation in the cited prior art to use the FAF signal as claimed to treat non-fluency disorders and particularly to treat reading disorders to improve reading comprehension. Further, if the treatment is not successful then there is no need to use it and the claims are not required to recite an actual degree of success.

Indeed, Applicant has demonstrated efficacy for the latter, see, Figures 15-18 and the Examples section of the pending application. Applicant is unsure how there would be a "high expectancy of success" for the different conditions and how such would result in a viable treatment just because the use of FAF has been used to treat speech disorders (*e.g.*, stuttering). The use of FAF to treat stuttering is well known and has been around for many years. Thus, if the use of FAF for the different conditions and/or to improve reading comprehension would have had such a "high expectancy of success" as alleged by the Action, why was it not used before the Applicants conceived the treatment option?

Applicant submits that such logic could be compared to the use of a drug to treat different conditions: if the drug treats one condition, it would then follow that there would be a high expectancy of success for a different unrelated condition because the patient would be treated. This rationale is unsupported by fact and is not the proper focus of patentability.

Further, as noted in the graphs associated with evaluation of the use of FAF to improve reading comprehension, the use of this treatment option with normal ability children resulted in no change while it had a positive affect on reading-delayed children (*see, e.g.*, page 27).

In addition, a wide range of conventional treatments have been attempted for the

various maladies, neither those treatments nor the pharmacological/drugs used for those different unrelated maladies are the same. For example, just because a treatment is used for autism does not mean there is a high likelihood of success that the treatment will work with ADD/ADHD or a reading disorder. Applicant submits that there continues to be a wide range of research into different treatments and conditions employing many types of therapies, including, drug, and other auditory therapies such as amplification and FAF or sensory (flashing light) therapies, as well as other therapy types (See attached Appendix of abstracts, of examples of research and treatment examples for autism).

Claims 7-9

Applicant respectfully submits that at least the treatment of dyslexia (Claim 7), ADD or ADHD, (Claim 8) and autism (Claim 9) are patentable over the cited prior art. Applicant has amended these claims into independent form. Applicant respectfully submits that at least Claims 7-9 are in condition for allowance and define over the cited prior art.

Claim 31

The Action alleges that speech disorders include speech sound disorders include disorders characterized by difficulty learning to physically produce sounds and rejects this claim as being obvious over Kehoe in view of SpeechEasy. Claim 31 is restated below for ease of discussion.

> 31. A method according to Claim 24, wherein the subject has a diagnosed learning disability ("LD"), and the step of transmitting is performed as a therapeutic treatment to promote improved learning.

Applicant respectfully submits that, even combined, Kehoe and SpeechEasy fail to teach or suggest that the FAF signal is a therapeutic treatment to promote improved learning (*e.g.*, reading comprehension, cognition, writing skills and the like). Kehoe is directed to enhancing fluency for speech disorders such as stuttering. SpeechEasy is directed to the output of FAF for treating stuttering. Applicant respectfully submits that Claim 31 is independently patentable over the cited art.

Applicant respectfully submits that Claim 5 is also patentable over Kehoe for the same reason.

> 5. A method according to Claim 1, wherein the subject has a diagnosed learning disability ("LD")<u>, and wherein the step of administering is carried out as a therapeutic treatment to improve reading comprehension and/or writing skills</u>.

<u>Claims 6, 27 and 32</u>

The Action rejects Claims 6, 27 and 32 as being obvious over Kehoe, SpeechEasy and Oster. The Action concedes that the combination of Kehoe and SpeechEasy does not teach treating a reading disability or impairment. However, the Action then states that Oster teaches a frequency modification feedback for reading speed and comprehension (considered a disability by the Examiner) and concludes it would have been obvious to use the Kehoe and SpeechEasy device to treat a patient with a reading disability per Oster. Applicant respectfully disagrees.

Oster uses a very different signal to improve reading speed. Oster does not identify that the treatment is directed to a user who has a reading disability, much less one with a reading disability. Applicant submits that many readers desire to increase speed and/or comprehension while being at a normal or age-appropriate level. Notably, the status of the user (normal or delayed) can indicate whether the FAF signal will be effective or not. <u>Indeed, the Applicant's own experimental work (comparing "normal" and "delayed" students) indicates that the FAF signal does not work on normal users. While improving reading skills/comprehension in delayed or users with reading disorders, the FAF signal has not been shown to improve comprehension on normal users</u>.

Applicant is attaching a copy of an article by Rastatter et al., entitled "*The effects of frequency altered feedback on reading comprehension abilities of normal and reading disordered children*", Neuroscience letters 416 (2007) 266-271. Applicant submits that the article is evidence of peer recognition of the significance of this new treatment option. This article, like the Examples section of the pending application, also indicates that the FAF signal is not effective on "normal" reading ability subjects.

Applicant respectfully submits that Claims 6, 27 and 32 are patentable over the cited art as even combined the references fail to teach or suggest the claimed features.

New Claims 68 and 69

Applicant also submits that new Claims 68 and 69, directed to treating a reading disorder to improve reading comprehension, are patentable over Oster and the other cited art. The claims are supported by the application and are in condition for allowance, which action is respectfully requested.

CONCLUSION

Accordingly, Applicant submits that the present application is in condition for allowance and the same is earnestly solicited. Should the Examiner have any matters outstanding of resolution, he is encouraged to telephone the undersigned at 919-854-1400 for expeditious handling.

Respectfully submitted,

Julie H. Richardson
Registration No.: 40,142

USPTO Customer No. 20792
Myers Bigel Sibley & Sajovec
Post Office Box 37428
Raleigh, North Carolina 27627
Telephone: 919/854-1400
Facsimile: 919/854-1401

CERTIFICATION OF TRANSMISSION

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Signature: ______________________
Cara L. Rose

APPENDIX A
EXAMPLES OF RESEARCH ON AUTISM FEEDBACK

J Autism Dev Disord. 2005 Apr;35(2):205-20. Links
Perception and production of prosody by speakers with autism spectrum disorders.

Paul R, Augustyn A, Klin A, Volkmar FR.
Southern Connecticut State University, USA. rhea.paul@yale.edu
Speakers with autism spectrum disorders (ASD) show difficulties in suprasegmental aspects of speech production, or prosody, those aspects of speech that accompany words and sentences and create what is commonly called "tone of voice." However, little is known about the perception of prosody, or about the specific aspects of prosodic production that result in the perception of "oddness." The present study examined the perception and production of a range of specific prosodic elements in an experimental protocol involving natural speech among speakers with ASD between 14 and 21 years of age, in comparison with a typical control group. Results revealed ceiling effects limiting interpretation of findings for some aspects of prosody. However, there were significant between-group differences in aspects of stress perception and production. The implications of these findings for understanding prosodic deficits is speakers with autism spectrum disorders, and for future research in this area, are discussed.
PMID: 15909407 [PubMed - indexed for MEDLINE]
Links
Effect of sensory feedback on immediate object imitation in children with autism.

Ingersoll B, Schreibman L, Tran QH.
University of California, San Diego, California, USA. bingerso@ucsd.edu
This study examined the effect of sensory feedback (e.g., flashing lights and sound) on the imitation performance of children with autism and typical children group-matched for mental age. Participants were administered an immediate object-imitation task with six novel toys constructed for this study: three with a sensory effect that could be activated by imitating the modeled action and three without a sensory effect. Although overall imitation performance did not differ significantly between the two groups, the imitation performance of the participants with autism was significantly higher with sensory toys than with nonsensory toys. Typical participants' imitation performance did not differ between the two sets of toys. Both groups played significantly more with the sensory toys during free play, indicating that sensory toys were more reinforcing for both groups. Additional results demonstrated that typical children used significantly more social behaviors during imitation than children with autism, but they did not differ in object-oriented behaviors, replicating previous findings. It is argued that children with autism may be less motivated to imitate by social interaction, but may be motivated to imitate to receive a nonsocial reward (sensory feedback).
PMID: 14714935 [PubMed - indexed for MEDLINE]

: Biol Psychiatry. 1997 Dec 15;42(12):1138-47. Links
Inadequate cortical feature maps: a neural circuit theory of autism.

Gustafsson L.

Attorney Docket No. 5218-101

Department of Computer Science and Electrical Engineering, Luleå University of Technology, Sweden.
The autistic syndromes are caused by neurological dysfunctions. The capacity of autistic individuals to form representations of previous sensory impressions, useful for the processing of present information, is impaired. Self-organizing feature maps are mathematical models of cortical feature maps and may be used to simulate cortical processing. Dysfunctional self-organization, resulting in disability to extract features from stimuli, is proposed as a neural circuit theory of autism. The nature and a possible cause of dysfunction self-organization are examined. It is shown that impaired feature detection is valid for explaining the memory function in autism, the lack of drive for central coherence according to Frith's theory of autism, and a number of impairments from the diagnostic criteria. Unequal levels of impairment of different cortical feature maps can account for the typically uneven intelligence profile of autistic individuals. Excessive inhibitory lateral feedback synaptic connection strengths are presented as one factor impairing the development of feature maps. Strong or excessive inhibitory lateral feedback synaptic connection strengths also cause high sensory discrimination and abnormal sensory responses, both documented in autism. A neural circuit theory for autism has been presented. For a proof of this neural circuit theory neurological investigations are required.
PMID: 9426884 [PubMed - indexed for MEDLINE]

Ann Neurol. 1999 Apr;45(4):495-503.
Links

Available online at www.sciencedirect.com

ScienceDirect

Neuroscience Letters 416 (2007) 266–271

Neuroscience Letters

www.elsevier.com/locate/neulet

The effects of frequency altered feedback on reading comprehension abilities of normal and reading disordered children

Michael P. Rastatter[a], Irene M. Barrow[b,*], Andrew Stuart[a]

[a] Department of Communication Sciences and Disorders, East Carolina University, Greenville, NC 27858, United states

[b] Department of Communicative Sciences and Disorders, Hampton University, Hampton, VA 23668, United states

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Abstract

The effects of frequency altered feedback (FAF) on the reading comprehension levels and error types of normal children and children with reading disorders were examined. Participants read aloud third, sixth, and ninth grade level material in non-altered auditory feedback (NAF) and FAF conditions. Comprehension improved significantly when the reading disordered children read aloud under the FAF listening condition, regardless of the reading level. Significant differences did not occur in reading comprehension for the normal readers under NAF versus FAF conditions. Reading disordered children produced significantly more reading errors as compared to the normal reading children under the NAF listening condition. No significant difference was found in reading errors between groups when reading under FAF regardless of the reading level, suggesting that the FAF signal produced a facilitory effect on reading errors in the reading disordered children. Theoretically, the FAF signal may have activated those cortical regions responsible for the relationship that has been shown to exist between lexical encoding and decoding of verbal and written material, respectively.

Keywords: Children; Reading disorders; Comprehension; Treatment; Feedback; Facilitation

The development of reading in children appears to result from the coordination of several interrelated, but distinct sub-processes. Evidence suggests that phonological processing abilities are primary for the development and use of word decoding, letter naming and serial naming [26]. However, the degree and level of semantic activation, phonological information processing and orthographic decoding are related to reading rate and comprehension [29]. Thus, deficiencies in reading must be carefully examined to determine which sub-processes may be involved in deterring successful completion of the task. Once the areas of difficulty are determined, treatment programs must be designed to specifically target the deficient sub-processes in order to have maximum success. Alterations in auditory feedback appear to impact the neurobiological functions related to phonological processing and positively affect the reading abilities of some children diagnosed with reading disabilities [4,14]. Therefore, this study sought to further examine the facilitory effects of one type of auditory feedback, frequency altered feedback (FAF), on reading abilities in children diagnosed with reading disabilities.

During the emerging literacy stage of beginning reading, the phonological decoding strategy is considered to be the primary strategy [26]. This method of decoding is an indirect route in which the user relies on their knowledge of the language sound system and their ability to manipulate and segment individual sounds or clusters of sounds into whole words requiring "at least three components – general cognitive ability, verbal memory, and speech perception" [1,3,16,17,20]. Additionally, it has been shown, through the implementation of rapid automatized naming (RAN) tasks, that phonological processing abilities correlate strongly with reading ability, and discriminate below from above average readers on variables of reading comprehension, word reading, and spelling [29]. Thus, when readers have deficient phonological decoding skills, a significant impact on reading efficiency and comprehension may result [5,6] which is referred to as the phonological deficit theory [18].

Although the phonological deficit theory is able to account for many individuals with reading disabilities, it may not account for all individuals. Wolf and Bowers [32] forwarded a theory on reading disorders termed the double-deficit hypothesis. This

* Corresponding author. Tel.: +1 757 727 5763; fax: +1 757 727 5765.
E-mail address: irene.barrow@hamptonu.edu (I.M. Barrow).

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theory rejects the claim that difficulties in lexical decoding are a result of poor phonological skills. Rather, the authors posit that phonological decoding anomalies and deficits in lexical access are functionally disparate processes, independent in their contributions to reading and decoding. According to the double-deficit hypothesis, children with dyslexia may suffer from deficits in phonological decoding, lexical decoding, or a combination of both [30,32].

While considerable behavioral data support the double-deficit hypothesis, a large literature exists providing convincing data supporting a central, neurobiological and physiological etiology for specific reading disorders implicating a primary deficit in phonological processing [22]. The application of functional magnetic resonance imaging technology has shown differences in the temporo-parieto-occipital cortical sites between children with normal reading skills and those with dyslexia. Specifically, anomalies were noted in the left-hemisphere parieto-temporal and occipito-temporal cortical fields during a variety of tasks that placed exceedingly complex and progressive demands on phonological processing mechanisms.

Evidence exists mapping compensatory neuro-processing mechanisms in reading disordered children. It appears that older people with dyslexia engage both the left and right inferior frontal gyrus during difficult phonological processing tasks, while younger children fail to do so [28]. Such data suggest that reading disordered adults recruit compensatory, homologous, right hemisphere region activation to help compensate for left hemisphere activation anomalies. Additionally, analysis of the relationships between reading skill and cortical activation has shown that a negative correlation exists between right occipito-temporal region activation and reading skill, suggesting that disordered readers rely on right, occipito-temporal regions for reading processes, as compared to the left hemispheric analogue reading network employed by normal readers. Even though cortical reading centers in reading disordered children appear disrupted, considerable levels of neuro-plasticity are evident in such populations, given the application of effective reading intervention programs.

A number of treatment programs exist for remediation of reading disorders [15,29,32] including the application of altered forms of auditory feedback. Evidence suggests that disrupted or altered auditory feedback impacts directly on phonological coding mechanisms underlying reading functions [4], providing support for the existence of the double-deficit hypothesis since reading improved when reliance on phonological coding operations were reduced.

Kershner et al. [14] proposed that a modified voice feedback (where high frequency spectral information was amplified) during a timed naming task improved letter-naming speed in a select sub-type of learning disabled children. For children exhibiting anomalies in speech-monitoring, high frequency filtering in the auditory feedback network effectively stimulated letter-sound memory associations that contribute to fluent reading. However, the frequency modification significantly imposed a disruptive effect on disabled readers with intact auditory functioning leading the authors to caution that additional research was warranted to determine positive performance benefits. Finally, while the authors proposed that their findings might suggest the presence of a physiological anomaly in the auditory pathways or cerebral hemispheres, it may not be possible to speculate the exact location of a lesion. At best, the data suggest certain reading disorders result from a delay in development or suggest the presence of some form of neuropsychological discrepancy.

In an investigation designed to improve functional reading capacity in reading disordered children, Brezinitz [4] employed auditory masking and reading acceleration. Results showed that reading acceleration improved reading performance in both normal and reading disordered children. However, the masking condition was shown to enhance the dyslexic children's comprehension, while proving disruptive to the normal readers. It was argued that auditory masking reduces the effects of impoverished phonological processing in reading disordered children, enabling a more effective utilization of orthographic codes, enhancing top-down contextual effects for the reading disordered children. In addition, oral reading errors in the reading disordered children decreased while reading speed increased. It was suggested that the presence of exogenous, auditory speech-competition influenced the "distribution of processing resources" allowing for reallocation or differential access and reliance on phonological, orthographic, and semantic processing mechanisms. While the underlying neural mechanicals accounting for their results were not speculated, it remains possible that modifications imposed on the auditory feedback system underlying sensory-motor encodings of speech output and processing of written material result from alterations in the signature of those cortical sub-systems with regulatory control over the central, neuronal mechanisms subserving language and speech production events, stimulating more normalized reading functions.

Frequency altered feedback also has proven to influence hemispheric activity of cortical fields associated with language production significantly impacting speech production mechanisms in populations of people who stutter. Specifically, an FAF signal was shown to alter qEEG activity in posterior cortical regions corresponding to the language neural substrate in people who stutter, possibly reflecting changes in neurogenerator status or dipol activity underlying verbal processing [19]. The cortical region enhancing effects may be due to the acoustic structure of the FAF signal. That is, the FAF signal shares frequency, time and amplitude characteristics of the human speech signal, albeit one-half octave higher than the speaker's voice fundamental frequency. As such, a speaker processes FAF as an endogenously produced "second-speech" signal, which has been shown to produce robust speech-production enhancing effects [12,13,24,25]. As a result, its application to the remediation of persons with reading disabilities appears warranted. Therefore, the purpose of the current investigation was to study the effects of frequency altered feedback (FAF) on reading functions in children with diagnosed reading disorders.

The participants were 27 students, 15 normal reading sixth grade students and 12 sixth grade students attending local eastern North Carolina middle schools diagnosed by their school as being reading delayed and were enrolled in a traditional reading program with phonological processing serving as the primary emphasis for habilitation. Each participants' overall

reading ability score on the Woodcock Johnson Reading Mastery Test—Revised (WRMT—R) [31] determined reading ability. Normal reading ability was defined as an age appropriate score. Delayed reading ability was defied as 1 or 2 years delayed relative to the age appropriate score. All participants had normal bilateral hearing sensitivity as determined by a screening protocol, normal or corrected vision, as reported by their parents or school personnel, passing scores for language screening [21] and average scores for receptive one-word picture vocabulary [9].

Participants read three passages from the Spadafore Diagnostic Reading Test [23], (one each at the third grade, sixth grade and ninth grade levels) under both non-altered feedback (NAF) and frequency altered feedback (FAF). Following the reading of each passage, the participant then read and responded to five multiple choice questions that assessed comprehension of the written material.

While reading, participants wore a supraaural headset employing a noise-cancelling microphone (Sennheiser model PC 130). The microphone output was fed to a digital signal processor (Casa Futura Technologies® model Pocket Speech Lab) before being returned binaurally to the participants' ears through the headset. Speech was unaltered for the NAF condition. In the FAF condition, the speech signal was shifted in frequency up one-half octave without delay. This alteration preserved the harmonic relationship of signal component frequencies [7]. Signal level to the earphones was adjusted to each participant's most comfortable listening level.

After administration of the standard assessment instruments, participants were given a short break. Upon returning to the testing room, the reading tasks and conditions were explained. Two separate passages for each reading level were available as test materials, which were counterbalanced across the listening conditions and participants. All of the reading tasks and conditions were audio- and video-taped for later scoring of decoding errors.

Comprehension scores and decoding errors for each condition were determined. Comprehension scores were based on the number correct for each passage with a perfect score being five. The total number of decoding errors and the total for each type of decoding error that occurred (phonological versus visual) for each passage was calculated for further analysis. The system employed for determining decoding errors was based on the method of Rastatter and colleagues [2,11,27,28] where the sub-systems or processes underlying the recognition of visual information can be identified. Such a method allows for direct assessment of phonological processes (auditory based mispronunciations, substitutions, repetitions) and visual processing functions (visually based omissions, reversals, insertions, repetitions—errors based structural descriptions). Two individuals, trained to code the responses, were employed to analyze error types. Inter-judge error type-by-error type agreement, as indicated by Cohen's *kappa* [8] was .88. Intrajudge Cohen's *kappa* agreement was .96. *Kappa* values above .75 represent excellent agreement beyond chance [10].

A three-factor mixed analysis of variance (ANOVA) was undertaken to investigate mean differences in total comprehension scores as a function of group, reading level, and auditory feedback. Significant main effects of group (F (1, 25) = 15.06, P = .0007, η^2 = 0.38) and level (F (2, 50) = 71.03, $P \leq .0001$, η^2 = 0.74) were found. A significant feedback by group effect (see Fig. 1) was also found (F (1, 25) = 10.84, P = .003, η^2 = 0.30). All other interactions were not significant (P > .05). In general, as reading level increased comprehension decreased. The normal reading participants had better comprehension than the reading delayed participants. Single degree of freedom contrasts were employed to investigate the significant auditory feedback by group interaction (see Fig. 1). The reading delayed participants had significantly higher comprehension with FAF as compared to NAF (P = .0002) while there was no difference between the normal reading participants in NAF versus FAF (P = .41). The reading delayed participants had significantly lower comprehension than the normal reading participants in NAF (P = .0001) while there was no difference between the groups in FAF (P = .18).

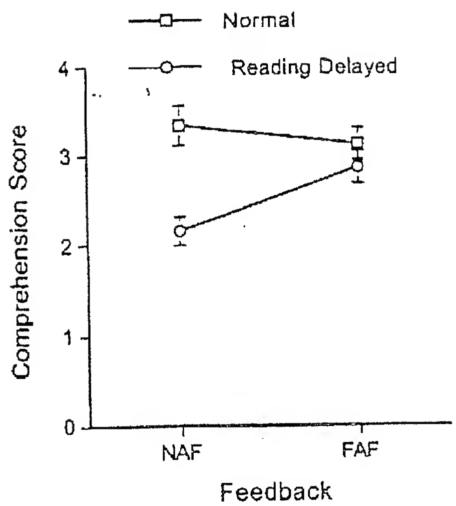

Fig. 1. Comprehension scores as a function of auditory feedback and group. Error bars represent plus/minus one standard error of the mean, P = .003.

A three-factor mixed ANOVA was employed to investigate differences in mean reading errors as a function of group, reading level and auditory feedback. A significant main effect of level was found (F (2, 50) = 166.69, P = .0001, η^2 = 0.87). A significant auditory feedback by group effect (see Fig. 2) was also found (F (1, 25) = 5.84, P = .023, η^2 = 0.19). All other main effects and interactions were not significant (P > .05). In general, as reading level increased errors increased. Single degree of freedom contrasts were employed to investigate the significant feedback by group interaction. The reading delayed participants had significantly more errors with NAF versus FAF (P = .0007) while there was no difference in errors with the normal reading participants in NAF versus FAF (P = .14). The reading delayed participants had significantly more errors than the normal reading participants in NAF (P = .0095) while there was no difference between the groups in FAF (P = .61).

Errors were further categorized as visual/lexical errors, those occurring when the sight-word strategy is used, but incorrectly, phonological errors, where multiple attempts at sounding out the word into sounds or syllables are observed, but the word remains

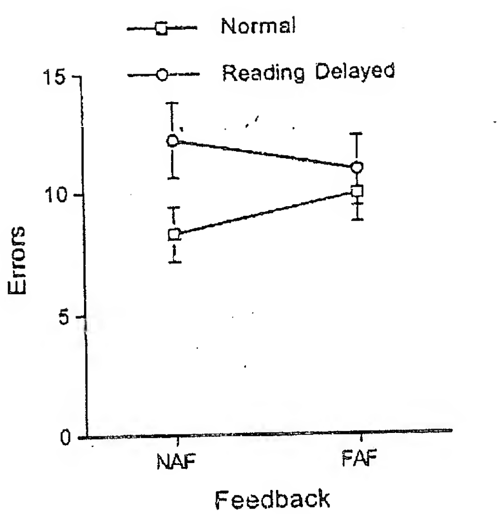

Fig. 2. Reading errors as a function of auditory feedback and group. Error bars represent plus/minus one standard error of the mean, $P = .023$.

mispronounced or miscued, or errors of omission. Error-type analysis showed that 92.6% of the total errors were classified as phonological, with visual-lexical and omission errors occurring at a rate of 4.5% and 2.9%, respectively.

The purpose of the current study was to investigate the effects FAF on reading comprehension, error rates and error type in a group of normal and reading disordered children. As reading levels increased, comprehension decreased for both groups of children. Such a finding is understandable given that the level of reading material increased to a grade level 3 years beyond the grade-equivalent reading comprehension level for the normal children. However, under the FAF condition, the results for the two groups were significantly different. Reading comprehension under the FAF condition significantly improved for the children with reading disorders, but no difference in performance was found for the children with normal reading abilities. Similar results were found for reading error rates. That is, while both groups committed more errors as reading level increased, the children with reading disorders committed significantly less errors under the FAF condition relative to NAF. This effect was not evident for the children with normal reading levels. Instead, no difference in error rate was found under the two conditions for the normal readers. Further, under the FAF condition the number of reading errors committed by the children with reading disorders was commensurate with those committed by the normal readers. These data support previous findings indicating the positive effects of FAF and may provide implications for treatment.

Analysis of the comprehension data revealed a significant two-way interaction between groups and listening conditions. Inspection of Fig. 1 shows that, for the reading disordered children, significant differences existed in comprehension scores as a function of auditory feedback, as compared to the normal readers. Reading comprehension improved significantly when the reading disordered children read aloud under the FAF listening condition, regardless of the reading material level. In fact, comprehension scores improved to the level nearly identical to that obtained by the normal reading group under the FAF condition, evidencing a similar response archetype for the two groups of participants. Comprehension scores for the normal readers, however, did not differ significantly between the NAF and FAF conditions. Such a finding suggests that while FAF proved capable of improving reading comprehension in the reading disordered children, it is not capable of generating significant and parallel improvements in comprehension levels for normal reading children. Such findings are in concert with those reported in the literature [4,14] and suggest that reading comprehension in reading disordered children is impacted favorably by the presence of the FAF signal.

While the children with reading disorder displayed better reading comprehension regardless of reading level, the underlying central processing operations that account for the similarity in response profile for the two groups of participants under the FAF are not clear at this point. Arguably, an increase in attentional processes may have contributed to the improvement in performance for the reading delayed children. However, based on the collective findings of the reading disorders literature, it appears that the processing strategies involved in stimulating reading comprehension ability were altered by the FAF signal, and most notably by impacting the extent and/or level of access to phonological processing mechanisms [4,20].

Breznitz [4] suggested that normal, developmental reading processes rely heavily on phonological mechanisms for processing written material. The presence of a non-congruent, auditory speech signal limited access to information processing provided by phonological decoding mechanisms for normal readers, resulting in the diminished levels of reading comprehension observed in her data. The auditory-speech competition provided in the experimental "masking" condition gained "automatic access" to phonological processing mechanisms. Such access was thought to create a resource-sharing problem within the phonological processing channels, thereby reducing reading comprehension capacity in the normal reading children.

While such a position is understandable for response conditions employing competitive, non-congruent, auditory-speech material, the FAF listening paradigm does not present a parallel listening environment. Perhaps the difference in findings between competitive, non-congruent auditory stimulus and FAF lies in the physical characteristics of the signal, and the type of linguistic load delivered by each condition. The linguistic processing load presented under FAF is identical to the speaker's verbal output. The only alteration that occurs in feedback under FAF is that the speech signal is shifted upward one-half octave with a total harmonic distortion of less than 1%. The overall feedback is representative of a "choral speech" effect where the auditory signal presents an experience of speaking in unison with another speaker. It is suggested that the choral-speech effect provided an environment that proved to be cognitively interfacing with the intended message. As a result, FAF fails to significantly impact reading comprehension of normal readers, as the phonological processing channels are capable of operating at total capacity. That is, a second-speech signal is capable of interfacing with the cognitive effort necessary to process and comprehend

written material in normal readers, while concurrently providing an enhancing comprehension effect for the reading disordered participants.

A similar pattern of results was found for the reading error data. In general, both groups of children committed significantly more errors when the reading level increased. However, the presence of FAF differentially affected the number of errors committed by the two groups of children as evidenced by the significant group by listening condition interaction. Post hoc tests showed that the reading disordered children produced significantly more reading errors as compared to the normal reading children under the NAF listening condition. However, significant differences did not occur in reading errors between groups when reading under the FAF listening condition. Such findings, as with the comprehension data, occurred regardless of the level of reading material, suggesting further that the FAF signal facilitated a reduction in reading errors in the reading disordered children.

The error data results are in concert with past evidence showing improved reading comprehension occurs under conditions of auditory competition in disordered readers by reducing reading errors [4]. The current error analysis, however, does not align with the position suggesting that a lexical processing rout was accessed for the comprehension data found under FAF. Of the errors committed, 92.6% were coded as phonological processing in nature. This finding held true regardless of listening condition, comprehension level, and group. Such findings suggest that phonological coding was the primary route employed by both groups in processing the current reading material.

The error data clearly show that the reading disordering children did not alter their coding strategy while reading under FAF indicating that the phonological processing channel was not disrupted. The error pattern classification system employed in the current study has been shown to be predictive of the processing operation employed to complete the tasks demands associated with both decoding and linguistic output functions [2,11,30,31]. Support for a lexical re-coding strategy theory would predict that lexical processing errors would have been expected to occur in the FAF data analysis. Such was not the case, however, and an alternate response mechanism must be held accountable for the improved reading comprehension observed under FAF.

The current findings suggest that the FAF signal was facilitory in effect, stimulating those central mechanisms responsible for phonological processing. Certainly, the current results are more congruent with the neurophysiologic literature suggesting that dyslexia represents an activation disorder within the language processing network underlying phonological procession, specifically left hemisphere posterior cortical systems. Theoretically, it stands that the FAF signal may have activated those cortical regions responsible for the relationship that has been shown to exist between lexical encoding and decoding of verbal and written material, respectively, similar to that observed in stuttering behavior [19]. While the current data suggests such may be the case, physiological evidence is called for examining the effects of FAF on cortical functions in reading disabled children reading under conditions of both NAF and FAF.

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